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ERTS IMAGERY AS DATA SOURCE FOR UPDATING AERONAUTICAL CHARTS

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16. Abstract

This report contains a portion of the San Francisco Sectional Aeronautical Chart where the shoreline boundaries of the lakes were actually revised from ERTS imagery. The photomechanical steps that were used are described along with the factors involved. The importance of hydrographic features on aeronautical charts and the advantages of using ERTS imagery for updating purposes are also fully discussed.

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PREFACE

The principal effort of this investigation to date has been learning how to utilize the hydro systems of lakes, impoundments, and streams. These elements are of extreme importance to both day and night air navigation because they are primary landmarks to which lesser, but still conspicuous, landmarks are related. In addition, the capability of ERTS imagery to point to other major landmarks, such as the details of land form configuration and vegetation cover, has indicated that space imagery will provide an invaluable augmentation to contours and geomorphology studies in the rendering of terrain graphics. The investigation has also shown that in certain ERTS frames and under certain conditions, innumerable cartographic elements such as roads, vegetation boundaries, cultivated areas, relief shadow patterns, and urban development patterns could be extracted by photomechanical technologies and procedures.

TABLE OF CONTENTS

ERTS IMAGERY AS DATA SOURCE FOR UPDATING AERONAUTICAL CHARTS

INTRODUCTION

Although the principal interest in ERTS imagery has been to keep present charts current, there has also been interest in design improvement or even in redesign of aeronautical charts. The investigative attitude has remained exploratory throughout the entire period of investigation; and although some of the following observations are unrelated to the stated purpose of this investigation, they will be mentioned in brief. At a later date, they may be the subject of a more complete investigation and report.

This report is devoted to the procedures used to evaluate and test the suitability of the ERTS imagery, to the techniques used to extract (isolate) those portions of most immediate interest, to the operational procedures that were used to incorporate portions of the imagery into the San Francisco sectional chart, and to recommendations to implement the utilization of space imagery on a continuing and routine basis. All recommendations are based upon the assumption that imagery will be available and at least as good in the future as that which has been examined (ERTS 1) to date. When ERTS is herein referred to, the reference is to all bands and all seasons. Particular frames and bands are referred to by band (frequency) and frame number. ERTS imagery is now renamed Land Satellite (LANDSAT) by NASA.

BACKGROUND ON AERONAUTICAL CARTOGRAPHY

Visual Aeronautical Navigational Charts are produced by the National Ocean Survey (NOS), NOAA, at scales of 1:250,000 (Terminal Area Charts), 1:500,000 (Sectional Charts), and 1:1,000,000 (World Aeronautical Charts--WAC's). These are by far the smallest scale charts produced for navigating wherein the navigator uses direct visual contact to observe features of the natural landscape and to reference these to the same features shown on his chart by various symbolizations and the artistic portrayal of the terrain.

These charts are designed to accommodate local, regional, and cross country flights. These scales are appropriate to the speed of modern aircraft and to the great distances they fly. Because of the speed being travelled, the scene observed by the pilot is rapidly and continually changing. When airborne, there are no visual equivalents of the profusion of direction signs, place identifier signs, and highway system markers which are used to aid the surface traveller. It is therefore important that the terrain and cultural features shown on the aeronautical chart have visual significance when viewed from the air. It is just as important that significant features as viewed from the air be shown on the chart; and so the chart must not only be properly designed, it must also be current.

To date, there is no puristic design for visual aeronautical charts. The elements incorporated into their design are borrowed from products of general cartography which utilize greater or lesser amounts of generalizations, ommissions, distortions, adjustments, and abstractions of the earth's surface and of the visible (and sometimes invisible) results of man's cultural endeavours. Cartography is to a great extent the art of selecting the required specialized data to be shown, devising the graphics and symbologies necessary to depict the selected data in its more or less correct geodetic place and directional attitude, and determining the amount of paper (scale) required to make the data selection readable and useful.

The principal difference between general cartography and aeronautical cartography consists of the guidelines and specifications used to select the data which is to be included on the chart. This difference points directly to the problem of compiling data from topographic source maps for incorporation into aeronautical charts. The guidelines and specifications used to construct topographic maps relate to the needs of the ground surface user community: surface travellers, engineers, geographers, land planners, and a host of others including the military. The prominence given to roads on topographic maps is based upon engineering specifications and use designations and not upon how prominent it appears from 10,000 feet. Shorelines are delineated to show areas that are always dry land (nautical chart sources are usually the opposite) and not to show how it might appear at any stage of tide or at the time a pilot views it. Name placements and annotations are carefully shown on topographic maps so as to match the existing highway, geographic, and directional signs

and guideposts which are placed for surface observers. Labeling tells the topographic map user not only that "this is a railroad", but which railroad. A church steeple, being a conspicuous landmark for ground observers, is given special labeling on the chart.

A pilot, however, sees no signs, place names, highway designations, or similar guideposts. He may not be able to find the church steeple because of his elevated perspective. He has little interest in the name of the railroad. He sees automobile junk yards, drag racing strips, the orange roof of a restaurant; he sees landfill and grading operations; he sees the new dirt roads in a recreational development; he sees construction for new lakes. None of the above are shown on topographic maps. Therefore, the topographic presentation does not meet the special needs of the aviator who must be able to rapidly and positively identify his position. To do so, he must be provided a special presentation on which only air-prominent detail is depicted and from which all clutter and confusing detail is eliminated.

The problems confronting the aeronatuical cartographer can be understood in that he must select and represent detail with little usable source material available that best presents the world as viewed by the aviators. He could have this information if he has available approximately 39,000 current aerial photos, scale 1:10,000, and if he has time to analyze them before the next printing deadline. He has neither. Aerial photographs are limited in availability, vary considerably in quality, and generally are at too large a scale to be used effectively in routine maintenance on charts with revision schedules as short and as rigid as aeronautical charts. The aeronautical cartographer is thus compelled to imagine, element by element, which of the features shown on 15-minute or 7.5-minute topographic quads (there are approximately 90 15-minute quads and 300 7.5-minute quads per 1:500,000 sectional chart) will be of the most significance to the pilot. He must also envision and present distinctive patterns or groupings for the pilot because the pilot rarely pins down his position by one check point alone, especially if he has become temporarily disoriented. He looks for a dominant landmark and then relates other features to it and to each other.

We can also now understand that the visual chart is never really completed. It is continually being made but is never finished. While the pilot is viewing the present day landscape, the source maps are presenting the landscapes of yesteryear. Accordingly, once the initial topographic and terrain relief base for the visual chart has been constructed, the construction of an aeronautical chart becomes basically a continuing process of revision: this is added to the chart; this is taken off the chart; this feature is given more prominence; this feature is given less prominence. These continuing changes are based upon the recommendations of general aviation pilots, upon determinations made by the flight edit teams of the National Ocean Survey, upon new editions of source maps, and upon any available aerial photography.

The difficulties of revising charts based upon the visual experience of general and flight check pilots are threefold. General aviation pilots often do not have time to report all that they see; and when they do report a landmark feature, such as a large new lake, they have no way of giving the exact location or of giving the right configuration or attitude of the feature. Source maps, which could ordinarily be used to obtain the location and configuration of reported landmarks, may be published for several years before they are revised; so even when a landmark feature is reported by a pilot, it may be as long as five years before it appears on a source map. When an identification and existence statement is given for a very large feature, such as Lake Anna on the North Anna River approximately 30 miles northwest of Richmond, Virginia, the revision problem is compounded: the Corps of Engineers knows the approximate configuration of a large lake when it is finally filled; but in the interim, the lake takes many shapes over a period of years; and it may eventually require several topographic quad sheets to map it. For those reasons, the Office of Aeronautical Charting and Cartogrpahy, NOS, was extremely interested in finding whether the vertical scene presented by space imagery would be suitable as a revision source for the Visual Aeronautical Chart series.

ACTUAL CHART REVISION USING ERTS

The geometric fidelity of ERTS imagery has been tested by others and has been found by most tests to meet mapping accuracy standards required for scales comparable to the Sectional and WAC series of aeronautical charts. In the matter of accuracy, aeronautical cartographers and general cartographers may look to different user objectives when designing the graphics. Geometric fidelity is essential to the engineer. Configuration fidelity (recognizability) is essential to the pilot. Of course, the configuration fidelity of the hydrography exhibited by ERTS is nearly perfect because it is the radiometric response to the true and currently existing configuration. The only limitation of ERTS is a matter of resolution, and the resolution of the hydrography is greater than can be used at the scale of 1:1,000,000 and is very adequate for scales of 1:500,000 and 1:250,000.

What needed to be tested, therefore, was not resolution or geometric fidelity, but how the ERTS imagery would combine with the aeronautical chart symbolizations already on the chart. The MSS (Multispectral Scanner System) imagery may ultimately provide what mathematicians have always dreamed of achieving: the perfect projection wherein the earth curvature is everywhere distributed evenly in minute increments. In the N-S direction, the ERTS image is nearly orthogonal with the series of pixels in each sweep absorbing its own minute share of the earth curvature from a horizontal attitude. It would seem, then, that all that would be further required would be to compensate for the E-W earth curvature by photographing the image when taped to a cylinder having the same curvature per 100 miles as the earth.

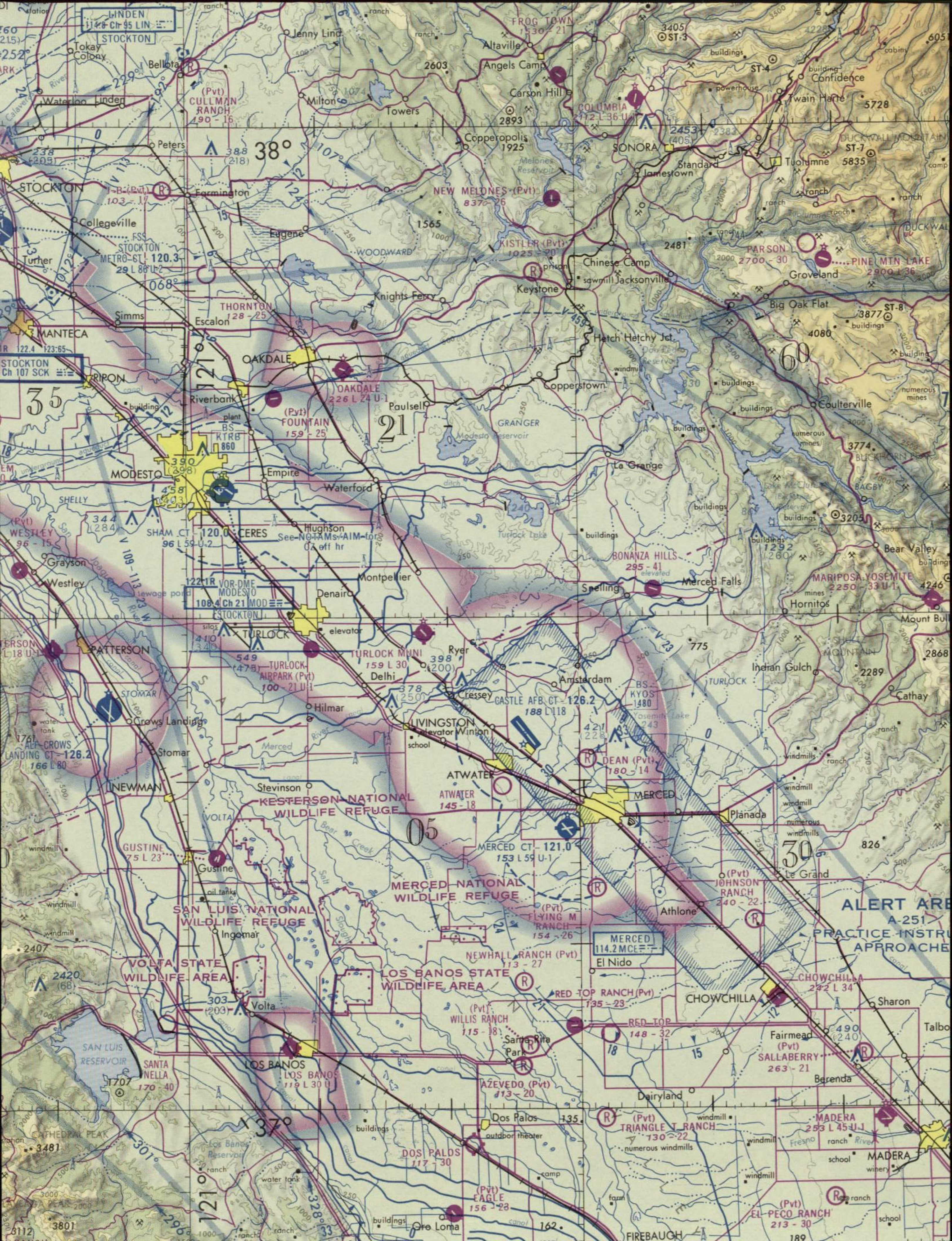
In contrast to the configuration fidelity of ERTS however, the individual features shown on aeronautical charts may or may not have some internal configuration distortion. When being transferred from original photography or from a plane survey, features such as small lakes may be geometrically averaged to the projection with no actual distortion of the configuration. Larger features may be distorted in compliance with the projection. What had to be tested was, when dealing with a hundred mile square area, how well features, such as Don Pedro Reservoir and the San Lois Reservoir, would adjust to the existing chart projection and graphics. Each arm

and cove at a reservoir must tie in to a complexity of existing chart configurations, including roads, power lines, contours, terrain relief portrayals, towers, dams, and streams.

For the test, the ERTS frames were enlarged to the scale of the Sectional Chart (1:500,000), using natural features identified on both the ERTS frames and the chart. To get the closest match, features were chosen in the diagonal corners of the ERTS imagery. The ERTS features were then enlarged photographically to the matching features on the sectional chart by the use of mylar measuring strips, and an enlarged transparency of the ERTS frame was made.

As expected, the projection differences did not allow for an overall match. However, individual ERTS features such as the Don Pedro Reservoir fitted remarkable well even though the reservoir is more than 15 miles in length. Many arms of the reservoir extend in all directions to follow the dendritic drainage patterns. The reservoir is confined by steep and narrow valleys. The fit to the existing contours, topographic symbols, and drainage patterns was, in this set of circumstances, very critical if the integrity of the chart were to be maintained.

The alignment of related features indicated that the ERTS could easily be matched to existing chart graphics, as evidenced by the portion of the San Francisco Sectional Chart that comprises the next page. All lakes and reservoirs shown on this chart were with one exception obtained directly from ERTS with no adjustments to existing chart elements other than to stream tips. The exception, Pine Mountain Lake (34 miles ENE of Modesto), was corrected in the regular manner from a flight check revision sketch with other source verification. Contours were not changed for any corrections. Few, if any, adjustments will be necessary between the ERTS and existing contours; but considerable changes would have been necessary to adjust the Pine Mountain Lake to the existing contours. This lake is clearly discerned on the ERTS frame <u>1344-18120 band 7</u> (see exhibit 1); and this configuration, requiring no adjustments to existing graphics, will be used to revise future editions of the San Francisco Sectional Chart.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Confidence
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Tuolumne
SONORA
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5835
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Big Oak Flat
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WILLIS RANCH
115 - 18
RED TOP
148 - 32
Fairmead
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have a possible influence on future concepts of charts that indicate to pilots flying at night under visual flight rules (VFR) the configuration of a tidal area during various tide stages or of shallows which are visually conspicuous.

Because of the difference of geometric configuration between ERTS and the visual aeronautical charts, long distances of shoreline cannot be transferred from ERTS to the chart. However, short segments of ERTS shoreline, as in the case of local shoreline revision, can easily be adjusted to match chart features.

LAKES AND IMPOUNDMENTS

Lakes and impoundments provide important and often primary landmarks for both day and night VFR flying. Not only are they highly visible, their shapes are unique, too. Their shapes tell a pilot much about the terrain, even at night.

But of all the landscape elements, lakes and impoundments are the most subject to change. Water is impounded for a number of reasons, some of which are temporary. Dams break and are not renewed; lakes are drained to store future snow melts; reservoirs are drained down during irrigation periods; fields are flooded; heavy rains and snow melts create sizable lakes which two months later may go dry. It might be years before some of these lakes appear on large scale maps; or they may never appear, but come and go between revisions.

The pilot is not interested in the histories of these lakes. He does not care if they are perennial or not. He sees a lake; and it gives him assurance or renders him temporarily confused, depending upon whether the lake is on his chart and whether it is recognized as being the same lake.

In this area of chart revision, ERTS can monitor and record changes faster than they can occur and faster than new editions of aeronautical charts are printed. What's more, the recording can be photomechanically extracted; or the recording can be hand traced at the very near scale of some of the visual charts (1:1,000,000) and will enlarge to the scale of the Sectional and local visual charts (1:500,000 and 1:250,000) while maintaining

more detail than is normally shown on the chart. Only nine ERTS frames would be required to revise the entire San Francisco Sectional Chart, which covers roughly 60,000 square miles of territory, not counting ocean area.

For the first time, ERTS makes the goal of keeping the hydrography current to within the near date of publication practical, realistic, and attainable. Further, ERTS, as stated before, is an automatic selector of the most prominent lakes. In addition to this, the ERTS display shows important groupings (a good landmark in itself) of the most prominent lakes and then shows which lakes within that grouping can be distinguished from the rest, as exhibited by the many lakes in the high Sierras shown on the north east corner of ERTS frame 1344-18120 band 7, July 2, 1973.

EVALUATION OF TERRAIN RELIEF

At one frequency or another and during one season or another, the most important aspects of the terrain relief are exhibited by ERTS. As in the case of relatively small streams and canals, the tendency of the pixel to saturate or collapse exhibits itself under certain conditions when recording terrain relief, a decided advantage when used by the cartographer in combination with contours and other sources to interpret and study land forms. As in the case of lakes and impoundments, ERTS, within its own lattice-work of recording by frequency bands, does an excellent job of isolating certain aspects of the terrain, including relief.

An example of this isolation by the saturation or collapse of adjacent pixels is the bluffs along the Yosemite Valley on ERTS frame 1340-18120 band 7, July 2, 1973 (easily found by following the east-trending narrow arm of Lake McClure over a small ridge, and then about thirty miles up the valley to the cliffs). Because of the early morning sun, the heavily shadowed side of the cliffs are dark and cold; the frequency emmission is so weak it is not recorded; and these dense shadows are then presented by the collapsed pixels in the same way as lakes. There are, of course, bluffs facing southeast which are casting no heavy shadow, but are quite bright and warmed up even by nine-thirty in the morning because of the high elevation and thin atmosphere. This effect seems to saturate

the pixel recordings.

Pixel saturation appears to occur much more easily than pixel collapse; and therefore the resolution of the bright, heated slopes is not nearly as good as the shaded slopes. Because of this same tendency of ERTS to over-react to strong emmission of the higher frequencies of the visible spectrum (as occurs when materials are brightly lighted and warm), the best time for recording the land forms is during the cooler months, although the lower sun angle may cause detrimental effects. Unfortunately, these are also the months when snow is likely to be present. But, there is a substantial range of frequency recordings (density) between the extremes of the heavily shadowed and bright reflectance of the landscape of Yosemite Valley; and some of these have been partially extracted.

Because the frequencies of ERTS bands 4 through 7 eventually wind up in the form of a monotone image, the various frequencies seem to be fighting among themselves at times in order to record their existence. These are the things that must be weighed when evaluating the relief on any particular frame. This is illustrated by ERTS 1255-18181, band 5, April 4, 1973, ERTS 1345-18172, band 5, July 1973, and ERTS 1345-18172 band 7, 1973. Band 5, April 4, 1973, shows relief in good detail. When viewed under four-power magnification, the terrain can be read very well. The effect of shadow overcasting can be easily judged. It would be a valuable guide source for traditionally rendered terrain relief portrayals, and it could undoubtedly be reworked into an original that could be reproduced.

By contrast, band 5, July 3, exhibits such strong contrasts of the summer vegetation that the relief can hardly be discerned. The detail that had been exhibited by band 5 in April is lost in July when summer vegetation dominates the landscape.

But, band 7 in July exhibits some (but not all) of the detail shown on band 5 in April. Band 7 is concerned little with the vegetation mantel. Although it does not exhibit the rich relief detail of the April band 5, it has a decided extra value because it shows the lakes and drainage systems, which are integrated with the relief and are thereby adding their weight to the overall terrain image.

EVALUATION OF VEGETATION MANTLE

As discussed above, during the summer months, the response of band 5 to the vegetation mantel is very strong and surpasses its response to relief shadowing. This fact was critical to any attempt at either the interpretation or extraction of the various components of the mantel. That the relief shadowing does not interfer with the extraction of summer mantel vegetation cover is exhibited by the final photo-frequency extractions obtained from ERTS 1344-18120, band 5, July 2, 1973 (see exhibit 4), wherein no relief characteristics can be ascertained. The concurrently-taken band 7, when subjected to density (frequency) extractions, exhibits not the vegetation, but the hydrography. Broad classifications of the vegetation mantel, including evergreen and deciduous brush lands, grasslands, and rockland (or barren), can be extracted by photomechanical techniques. In addition to the above, there are a variety of croplands which can be extracted along with the broader vegetation classifications. Crop varieties are of little concern to air navigation, but the general visual aspect of cropland is significant to air navigation.

EVALUATION OF CULTURAL DETAIL

It is typical of band 4 that little of the cultural aspects of the landscape is noticed by casual observation. But band 4, which as a rule presents a very drab presence and may at first glance appear to be the result of some bad photographic developer when the print was made, is a very revealing frequency when one gets out the four-power glass and begins to see what is presented. Band 4 is responsive to the green visible spectrum, so the seasons exert a great influence. There is a great difference in band 4 of April and band 4 of July. Band 4 also points out that the ERTS image is a gross product of contrasts. These contrasts vary by band and by season; and often as not, the image presented is an image of ommission, and not transmission, as characterised by ERTS E 1256-18235, band 4, April 5, 1975. This frame is characteristic of the lush cool countryside of the San Francisco Bay area in April. The response is so general that there appears little detail.

This general response, however, provides a background for the finer detail to which band 4 does not respond, such as concrete. By contrast

with surrounding response, the concrete runways of the Napa county airport (in the lower right hand corner of the frame) are clearly defined, as is the concrete of highway US-40. In the same frame, the concrete and masonery of the cities of Napa and Vallejo, of the resort town of Lakeport and other recreational facilities on Clear Lake, and of the mining operation near Clear Lake are clearly identifiable. The recreational facilities on Lake Berryessa are also well defined along with the coastal beaches.

That frame contains hundreds of signatures of unknown origin which are so strong that several adjacent pixels come up blank (as white). That these are bona fide signatures and not snow, small clouds, or photographic impurities is established by comparing the frame with a later frame, ERTS band 4, July 4, 1973. This later frame presents a drastic change in the greenery signatures, but it nevertheless points to many of the strong signatures. The Napa Airport runways form an arrow which points to one that is less than two miles from the airport. By contrast with the above frames of band 4 which in a subtle fashion show many details of the culture, band 7 of the same area (ERTS E 1364-18225, July 22, 1973) shows none of the cultural detail; but the hydrography is so strong that even the comparatively narrow Russin and Eel Rivers can be traced with no glass.

ANALYSIS OF THE EVALUATIONS

Although there are many possibilities for the cartographic exploitation of ERTS imagery, the evaluations indicate that the best possiblity for immediate application would be to extract the hydrography from band 7 imagery for direct incorporation into the sectional series of aeronautical charts. The evaluations also indicate that ERTS has been found to be an automatic selector of the most prominent lakes, waterways, highways and limits of heavy urban development. It is a natural selector of the most prominent watercourses, even if there is currently no stream flow in those watercourses. For those reasons, the relatively limited (as compared to some other forms of imagery) resolution has the very strong compensating cartographic advantage of being able to point out those features which would be most recognizable by pilots.

Techniques will undoubtedly be developed to incorporate cartographic elements such as streams, roads, and vegetation mantels into the charts; but because these features tend to be continuous, they would be difficult to adjust to the present chart projections. Terrain relief and orthophoto maps will run into the same problem. At present, they won't fit the projections; and these features cannot be mosaicked. The application of the above elements would best be accomplished by the correction of the total ERTS image to the Lambert Conformal Conic distortion. Terrain relief, in addition to the problem of distortion, is confronted with the problems of shadow reversal (although ERTS exhibits natural shadowing), shadow overcasting, and portions of the landscape which, although steeply sloped, are "blind" because of a directional attitude that casts no shadow. Also, other background tones, many as strong as the relief, would create reproduction problems. All of these problems could in various ways be corrected, but to correct them would take time. Since it is almost certain that there will be great progress in the overall development of ERTS technology, especially in the area of projection accommodation, the current priority was given to what we can use now. In the meantime, ERTS and the existing cartographic products will continually be coming closer together.

TRANSFER OF ERTS HYDROGRAPHY ONTO CHARTS

EXTRACTION OF LAKES AND IMPOUNDMENTS

The image frame used to extract the ERTS lakes and impoundments was ERTS E-1344-18120, band 7, July 2, 1973, see exhibit 2. To minimize the possibility of perpetuating any photographic processing flaws that might have existed because of bulk processing of the ERTS nine inch format, the extraction process was begun with the original ERTS 70mm positive transparency. This transparency was enlarged to the scale of the aeronautical sectional chart. A reproduction scale relief positive was made from the sectional chart, containing lightly pencilled drainage systems and the lakes. Two ERTS negatives and then positives were made at the enlarged scale: one a high contrast and one a normal contrast that retained as much detail as possible. The high contrast film was further processed to isolate the ERTS lakes. The normal detail contrast one was made as a "slave" image which accompanied the separated lakes, and it was used during the mosaicking to help position the extracted lakes.

SLAVE IMAGE

Since the ERTS lakes and impoundments were completely separated out from the rest of the image detail and since these lakes must be hand positioned by the mosaicking process, the separated hydrography does not in itself contain sufficient detail for mosaicking. Therefore, the procedure followed was to mosaic the slave, which was rich in terrain detail, to the combined reproduction positives of the relief and drainage plates; and then match the extracted lakes to the same lakes as shown on the slave.

MOSAICKING THE SLAVE

The purpose of the mosaic was to place each individual lake in its averaged geodetic position in such a way that individual arms of each of the lakes were in proper alignment with the streams and were also in accord with the local relief.

To do this, the slave film positive (4 mill) was sliced up so that each individual lake could be hand adjusted to the streams and relief and taped to a carrier sheet. The extracted lakes were then matched to the lakes on the mosaicked slave and taped to a separate carrier sheet. In addition, some of the detail from the drainage plate was scribed on the extraction film. These engravings were then filled with film marker wax so that they could be used later as registration marks for composing the ERTS lakes with the existing reproduction negatives.

CREATING THE SHORELINE

The lakes on the mosaicked film positive are a copy of the ERTS imagery, which is a solid and very detailed image. As much of the original imagery as possible was retained and printed as solid/screened watertint on the chart. To retain all of the original ERTS imagery, the shoreline of the lake was created to go to the outside of the tint (original imagery) so that the total lake imagery would be slightly exaggerated. The shoreline could just as easily have been made to form the inside boundary of the lake. With the shoreline running to the outside of the imagery, however, very small lakes would be successfully reproduced. The following photomechanical steps produced the shoreline of all the lakes simultaneously.

A. An ordinary contact negative was made of the mosaicked ERTS lakes. This is the true imagery and was used as an open window mask, along with a 15% screen, to make the lake tint.

B. From this negative, a duplicate negative was made, using a high speed duplicating film to spread the lake image and using white transluscent vinyl sheeting next to the vacuum frame to prevent any pin-point light source effect.

C. This spread negative, when masked by the normal-sized positive, produced the shorelines (see exhibit 3) portion of the San Francisco Sectional Chart found earlier in this report.

COMPOSING THE SHORELINE AND WATERTINT

A. The shoreline, at the pre-composition stage, had matchmarks in the form of the portions of drainage which were scribed on the ERTS lake extraction previously described. This same drainage existed on the reproduction plate containing the shoreline. The new work was inset in a full-size sheet of plastic or film, fitted to the drainage of the existing reproduction material, and punched to match the other reproduction materials. The drainage used as matchmarks was then removed.

B. The solid lakes film (used later for watertint) was then similarly inset in a large sheet of plastic, matched to the shoreline, and punched to match all other reproduction materials.

C. Both plates were then composed with the appropriate reproduction materials, requiring normal opaquing and composing procedures.

ERTS UTILIZATION

CURRENT USE

When the ERTS imagery in one frame was compared to the existing chart, there were eight discrepancies within the 100 mile square area of a magnitude that could, under certain conditions, contribute to pilot disorientation. Some of the discrepancies were the result of lakes being

drained or drying up; some were the result of new lakes; and some were the result of changes in configuration because of changes in water level. The hydrography was observed over the winter, spring, and summer seasons of 1973. The changes were judged to be of permanent or semi-permanent nature rather than created as the result of seasonal change, sudden flooding, or temporary drainage.

Because of these discrepancies, all lakes on the chart were replaced by ERTS lakes, within the 100 x 100 mile frame. The following guidelines and exceptions were used: (1) The lakes were those interpreted and identified positively as lakes; and (2) any imagery which could not be positively identified as lakes (such as bluff shadow, promontory shadow, or cloud shadow) was omitted. Some features were shown that were obviously holding ponds contained within a framework of levees and were not judged to be irrigated fields even though they might at some time be out of water. If later reported to go dry intermittently, the appropriate symbolization will be shown. Lakes shown on the chart which were not shown by ERTS were deleted, with the exception of some irrigation impoundments that could be intermittent because of greater than planned run-off. Those lakes will be watched for indicated change of classification.

CONTINUING USE

On a systematic basis, all the hydrography shown on the visual charts (1:250,000, 1:500,000, and 1:1,000,000) will be revised using ERTS imagery as a data source (not a sole source).

OTHER APPLICATIONS

Almost all the data shown on the ERTS imagery is of significant cartographic interest. Both cartographic and reproduction technologies need to be developed which will integrate the various elements of the imagery with other data sources.

CONCLUSIONS AND RECOMMENDATIONS

The scientific development, logistics management, and utilization of space imagery will develop into a cartographic discipline of major importance which will be closely aligned with climatology, geomorphology, and geography.

Remote sensing specialists should be developed who are trained to specify source data orders according to reliable predicted results. From the continuing study and comparison of various features and identical sets of imagery recorded during different periods and climate conditions, the specialist will become familiar with the characteristics of the imagery and with the earth landscape to an extent never before possible. The cartographer will be able to make better decisions about how to show or represent the earth because he will have a much better comprehension of the earth. In addition, the remote sensing specialist will be required to make judgments based upon the analysis of conditions concurrent to the data, such as haze, fog, air pollution levels, and temperatures. He will need to know the vegetation cycles as related to individual orbits. He will need to know characteristic signatures of features and materials of the landscape in addition to the vegetation mantel. He will need to know these things in order to buy the imagery he needs and to properly interpret the imagery he receives.

But because of this more intimate knowledge about the earth, the future cartographer will greatly expand his ability to serve in other areas such as land use studies, forest management studies, and waste land utilization studies. The present cartographer should learn as much about the utilization of space imagery as he can, apply it where possible, and pass what he learns along. We are just now beginning to compile the body of knowledge that will be needed by future cartographers with remote sensing specialities.

And when we say <u>he</u> and <u>his</u>, we also mean <u>she</u> and <u>her</u> because the field is becoming equally attractive to men and women.

EXHIBITS

The following are the descriptions for the four exhibits that are attached to this report.

EXHIBIT 1 -- BAND 7 - ERTS

This is the kind of imagery that is suitable for extracting lakes and impoundments. It is provided during the season of greatest contrast between the water and surrounding vegetation.

EXHIBIT 2 -- EXTRACTED LAKES

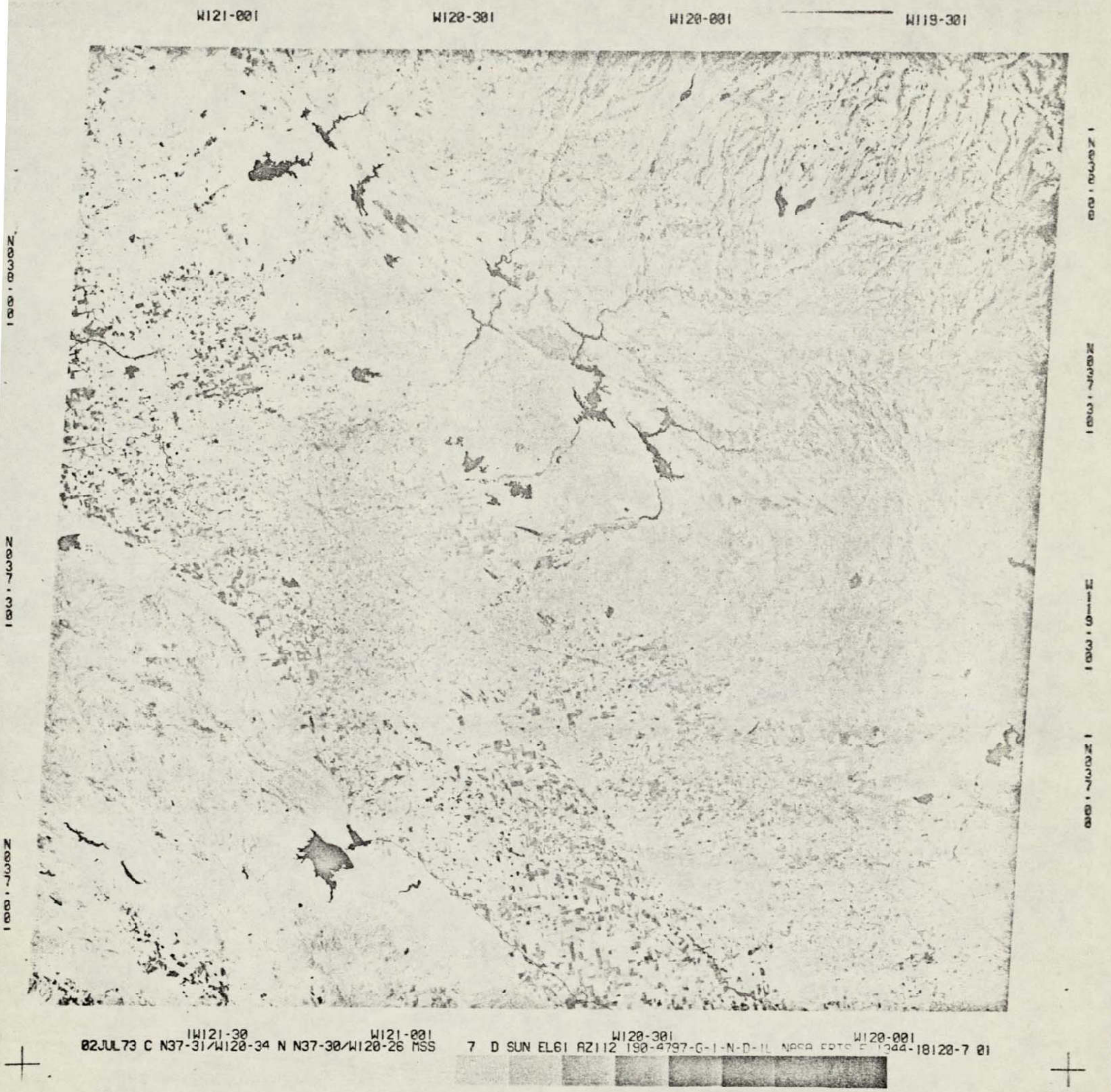
These images are lakes and impoundments that have been extracted by photomechanical density recordings. From a negative, one normal positive similar to this will be made, then one duplicate negative using high speed duplicating film to make a "spread" negative.

EXHIBIT 3 -- LAKE SHORELINES

When the normal positive of lake images was overlaid on the spread negative, the resultant print produced the shoreline positive shown. The width of the shoreline was controlled by the amount of spread. The shoreline could have been placed to either the outside or inside of the imagery or centered on the edge of the imagery by using a partly spread negative and partly shrunken positive.

EXHIBIT 4 -- LINEWORK OF VARIOUS FIELDS, WOODS, AND LAKES

The lines shown here were obtained directly from ERTS imagery. They represent boundaries of various kinds such as lakes, crop fields, woods, and timberline. Also represented are areas that have no boundaries. No attempt was made to determine identities. The experiment was made to test the ERTS imagery resolution. Since the boundaries produced were as sharp and as fine as the linework needed for aeronautical charts, the resolution was judged to be satisfactory. The technique used here was similar to that described in the section <u>Transfer of ERTS Hydrography onto Charts</u>.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02JUL73 C N37-31/W120-34 N N37-30/W120-26 MSS 7 D SUN EL61 AZ112 190-4797-G-1-N-D-1L NASA ERTS E-1344-18120-7 01

EXHIBIT 1

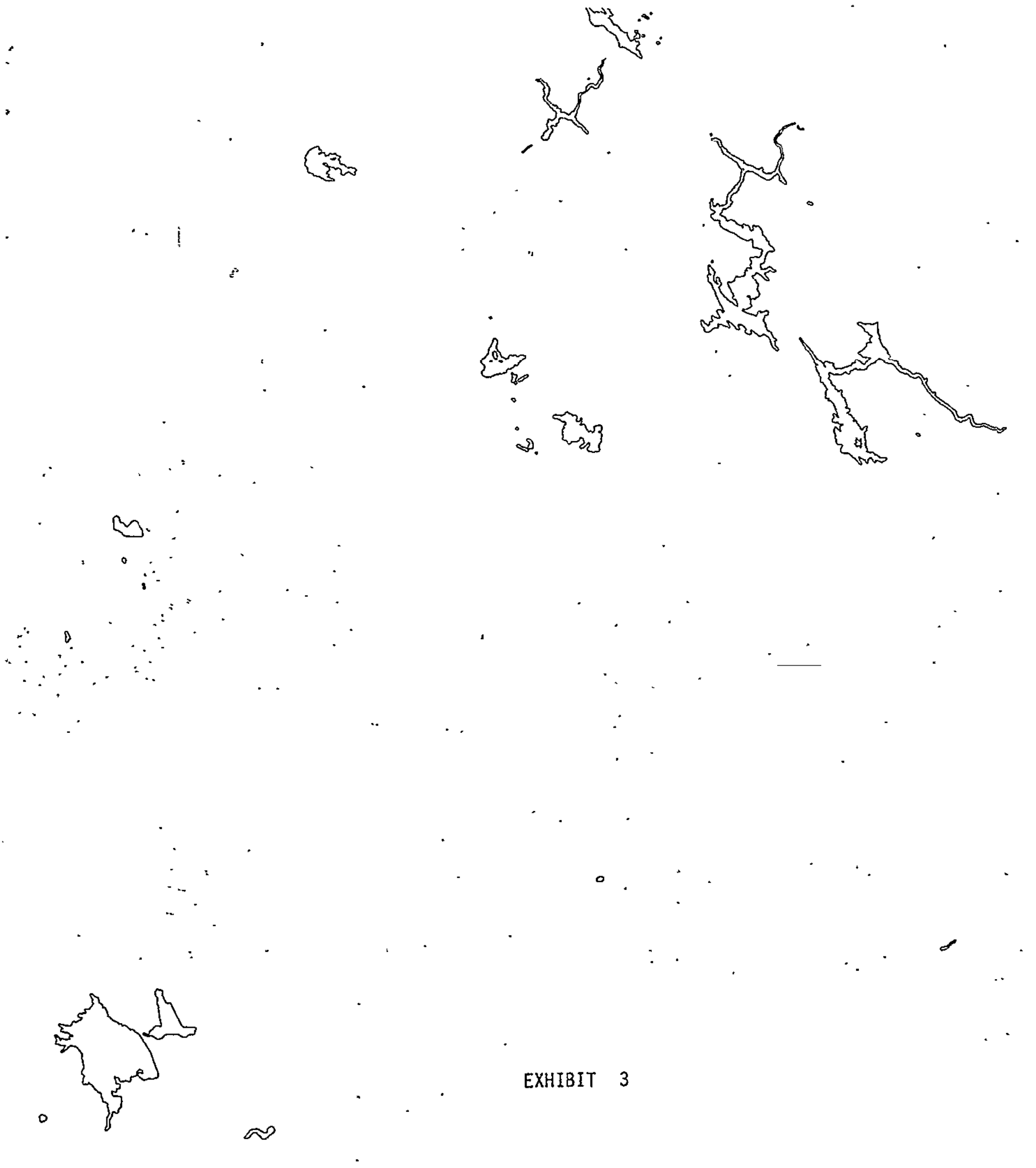

EXHIBIT 3

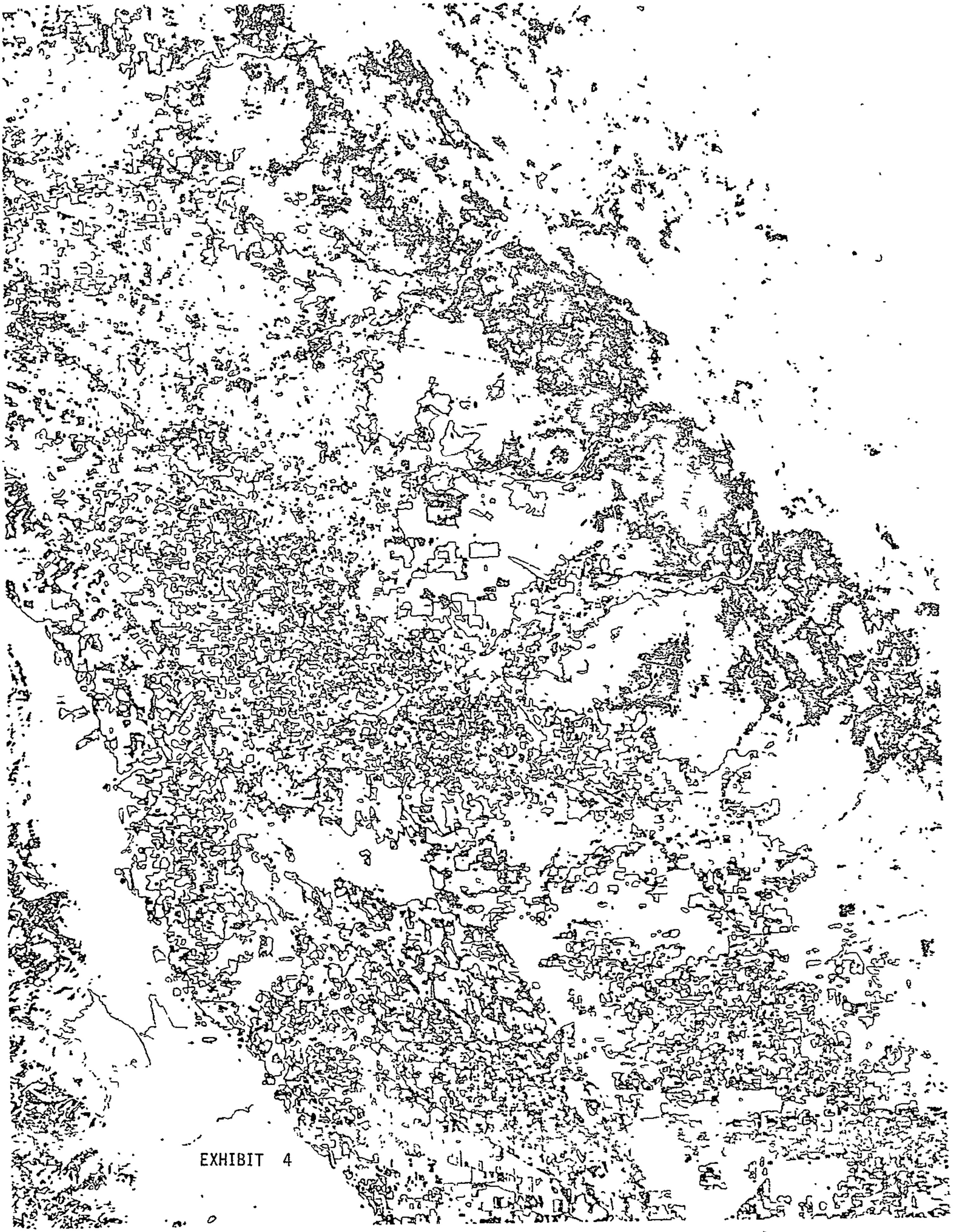

EXHIBIT 4